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Retransmission of Hydrometric

Data in Canada

SR 28190

Applied Hydrology Division
Department of the Environment
Ottawa, Ontario, Canada
K1A 0E7

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Quarterly Report for Period October-December 1976

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14. Supplementary Notes

Prepared by I.A. Reid, R.A. Halliday, A.C.D. Terroux

15. Abstract

Data collection Platforms have been installed at 23 sites in remote areas of Canada for transmittal of water level and other water resources data. The near real-time data are used for water management purposes. The system has met all requirements and demonstrates the suitability of transmitting hydrometric data by satellite.

The installation of the Landsat/GOES DCS downlink at the Prince Albert, Saskatchewan Satellite Station scheduled for completion in May 1977 is proceeding as planned.

Notes on an oral report to NASA's Water Resources Panel are included as an Appendix.

I. Introduction

The Water Survey of Canada operates over 2 400 hydrometric stations at which water level data are collected. Because of the isolated locations of many of these stations, it usually is not economically feasible to telemeter data from the sites by conventional means. For this reason an experiment was conducted which involved transmitting data from nine sites by means of Landsat 1. The technical suitability of the system was demonstrated and in response to a demand for near real-time data from additional sites, it was decided to implement a larger network. In this way, it should be possible to determine the benefits and costs associated with a larger operational system.

II. Techniques

Data Collection Platforms have now been installed at 23 sites. An additional 6 DCPs may be installed in 1977. The sites (Figure 1, Table 1) were selected on the basis of real time data needs for water management purposes. Water level data are transmitted from all sites while additional parameters, mainly meteorological data, are transmitted from some sites.

Water levels are sensed at Water Survey of Canada gauging stations by a float and pulley or by a servomanometer that senses the static pressure in a nitrogen purge system. Water level is usually recorded on a strip chart recorder. At those stations where DCPs are installed, an analogue to digital shaft position encoder (the Stevens Memomark II) is used to encode and store 16 bits (4 BCD digits) of water level data for transmittal by the DCP.

Precipitation data are obtained using a Fisher and Porter weighing type precipitation gauge. The gauge can be equipped with a Telekit for telemetering of data. The gauge is connected to a serial digital interface designed by Atmospheric Environment Service, (AES) Department of the Environment. The interface is known as a Hydrometeorological Automatic Recording and Telemetering System (HARTS). Air temperature in the HARTS system is sensed by a platinum resistance bulb thermometer. A precision thermistor (YSI 44033) connected directly to the DCP is also used in some other cases.

The data transmitted by DCPs are processed by NASA, then sent to Canada in two ways. The first is by land line to the Canada Centre for Remote Sensing in Ottawa. The data usually arrive shortly after each orbit of the spacecraft. At CCRS the data are recorded simultaneously on a teletype hard copier and on magnetic tape. A software data retrieval system sorts the user platforms, reformats the data into engineering units and stores

FIGURE I

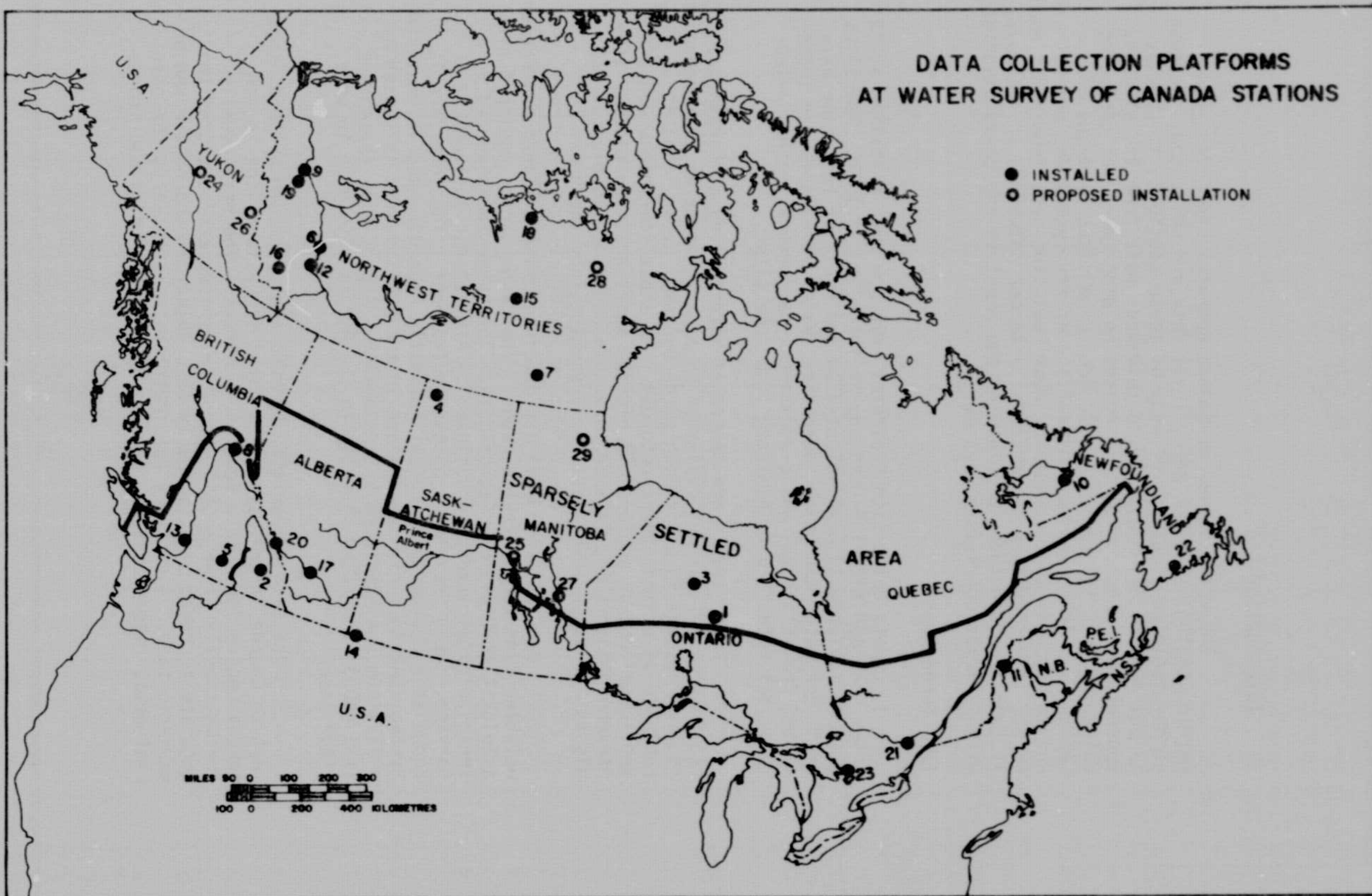
DATA COLLECTION PLATFORMS
AT WATER SURVEY OF CANADA STATIONS
INSTALLED
PROPOSED INSTALLATION
U.S.A.
YUKON
NORTHWEST TERRITORIES
BRITISH
COLUMBIA
ALBERTA
SASK-
ATCHEWAN
Prince Albert
SPARSELY
MANITOBA
SETTLED
AREA
ONTARIO
QUEBEC
NEWFOUNDLAND
P.E.I.
N.B.
N.S.
U.S.A.
MILES 50 0 100 200 300
100 0 200 400 KILOMETRES

TABLE 1

LOCATION OF DATA COLLECTION PLATFORMS

INSTALLED AT HYDROMETRIC STATIONS	DATE INSTALLED	DCP	LAT.	LONG.
1) Albany River above Nottik Island	Jan 13, 73	6102	51° 38'	86° 24'
2) Carney Creek below Pambrun Creek	Mar 25, 75	6126	50° 10'	116° 35'
3) Winisk River at Kanuchuan Rapids	Sept 27, 74	6137	52° 58'	87° 42'
4) Lake Athabasca at Crackingstone Point	Sept 19, 72	6150	59° 23'	108° 53'
5) Snow course No. 5A Mission Creek	Oct 31, 75	6232	49° 57'	118° 55'
6) Mackenzie River near Wrigley	June 7, 73	6260	63° 16'	123° 36'
7) Kazan River at Outlet of Ennadai Lake	Sept 19, 72	6353	61° 16'	100° 58'
8) McGregor River at Lower Canyon	July 26, 76	6354	54° 16'	121° 40'
9) Mackenzie River at Sans Sault Rapids	May 31, 73	6366	65° 46'	128° 45'
10) Churchill River at Muskrat Falls	Aug 7, 75	6502	53° 15'	60° 47'
11) St. Francis River at Outlet of Glasier Lake	Aug 13, 75	6504	47° 12'	68° 57'
12) Root River near the Mouth	July 15, 75	6512	62° 29'	123° 26'
13) Nahatlatch River below Tachewana Creek	Oct 20, 75	6514	49° 57'	121° 52'
14) Battle Creek at International Boundary	Oct 22, 75	6541	49° 00'	109° 25'
15) Hanbury River above Hoare Lake	July 5, 76	6547	63° 36'	105° 09'
16) South Nahanni River above Virginia Falls	July 15, 75	6572	61° 38'	125° 48'
17) Bow River below Carseland Dams	Oct 27, 75	6574	50° 50'	113° 25'
18) Ellice River near the Mouth	Apr 22, 76	6507	67° 42'	104° 08'
19) Mountain River below Cambrian Creek	May 7, 76	6542	65° 14'	128° 34'
20) Ridge of Mount Rhondda above Peyto Glacier	Oct 6, 76	6517	51° 38'	116° 33'
21) Rideau River at Ottawa Test Site (now in operation in the GOES mode)		6521	45° 23'	75° 42'
22) Grey River near Grey River	Sept 13, 76	6210	47° 45'	56° 56'
23) Severn River above Wasdell Falls	Sept 14, 76	6524	44° 46'	79° 18'
PROPOSED				
24) Pelly River at Pelly Crossing		6501	62° 50'	136° 35'
25) Moose River near Moose Lake		6511	53° 38'	100° 19'
26) South MacMillan River at Mile 249 Canal Road		6522	62° 55'	130° 32'
27) Lake Winnipeg at Berens River		6527	52° 21'	97° 00'
28) Back River below Deep Rose Lake		6544	66° 05'	96° 30'
29) Seal River below Great Island		6571	58° 54'	96° 17'

individual user files on disk. The user may then access the data file, usually daily, using either a teletype or telex remote terminal.

The second way that data are received from NASA is by punched card and uncalibrated computer listings about two weeks after transmittal by the DCP. These data are delivered to the Canadian Embassy in Washington, D.C., then carried by diplomatic bag to the Department of External Affairs in Ottawa. External Affairs then mails the data to the user. The cards are run in computer programs that sort the data and perform the conversion to engineering units. Data produced in this way are used to generate statistics on DCP performance, for quality checks and for archival purposes.

III. Accomplishments

Platform 6517 was installed on the ridge of Mount Rhondda on the Alberta-British Columbia Boundary at an elevation of 2 900 m on October 6, 1976 by the Glaciology Division. A memory is used to store hourly values of two voltages from which temperatures can be computed. Although the platform is sitting unprotected on a ridge, it has operated continuously since installation.

DCPs 6260 (GE), 6504 (BBRC) and 6541 (BBRC) were sent for inspection to the Instrumentation Section, Glaciology Division. DCP 6260 would not transmit in the 180 second setting even though it transmits in the 90 second setting. Replacing IC V3 on the programmer assembly board (A3) corrected the fault. This sort of failure is considered normal after a few years of operation. Standard modifications were made to the Frequency Generator (FG) and Central Processor (CP) boards for DCPs 6504 and 6541.

Table 2 is a summary of the data retransmitted for Landsat cycles 34 to 38 inclusive covering the period October 1 to December 29, 1976. During this period slightly less than 16 000 transmissions were processed. The relatively few transmissions are due to fewer DCPs on the air. A number of DCPs particularly in the Mackenzie River Basin were purposely turned-off after the freeze-up. Table 3 summarizes the results of messages received at Fairbanks, Goldstone, and Greenbelt, Maryland for cycle 38.

The installation of the Landsat/GOES data collection system down-link at the Prince Albert Satellite Station scheduled for completion in May 1977 is progressing as planned.

TABLE 2

SUMMARY OF RETRANSMITTED DATA - OCT. 1 TO DEC. 29, 1976

Daily Mean Transmissions per cycle for cycles 34 to 38 (Landsat-2)

(Transmissions received simultaneously at two or more sites are counted only once).

Platform	34	35	36	37	38	Daily Max.	Daily Min.	Total
6102	8 (18)	8 (18)	8 (18)	6 (18)	5 (18)	11	1	630
6126	5 (18)	6 (18)	5 (18)	4 (14)	1 (7)	9	1	344
6137	17 (18)	17 (18)	15 (18)	8 (16)	7 (15)	21	1	1 126
6150	28 (18)	29 (18)	29 (18)	25 (18)	26 (18)	34	12	2 469
6210	6 (18)	6 (18)	6 (17)	6 (18)	6 (18)	10	2	520
6232	12 (18)	13 (18)	13 (18)	13 (18)	16 (18)	19	7	1 206
6260	35 (18)	16 (14)	-	9 (1)	13 (5)	46	1	926
6353	32 (18)	32 (18)	30 (18)	28 (18)	30 (18)	37	13	2 752
6354	6 (18)	9 (18)	10 (18)	10 (18)	10 (17)	19	1	806
6366	27 (18)	26 (18)	20 (4)	-	-	30	6	1 040
6501	4 (2)	4 (2)	-	1 (7)	1 (15)	6	1	48
6502	10 (18)	10 (18)	8 (18)	6 (11)	6 (3)	13	1	573
6504	9 (13)	-	-	-	10 (10)	16	1	221
6507	16 (18)	11 (17)	2 (8)	-	-	18	1	500
6512	8 (18)	5 (11)	-	-	-	13	2	207
6514	8 (18)	7 (18)	5 (18)	7 (18)	6 (18)	12	1	586
6517	10 (2)	Loaned to Glaciology				14	6	20
6522	13 (12)	9 (3)				15	7	180
6524	10 (18)	10 (18)	10 (18)	11 (18)	11 (18)	16	2	918
6541	3 (18)	3 (14)	-	13 (9)	-	18	1	211
6547	17 (18)	12 (14)	14 (1)	-	-	26	2	489
6572	8 (18)	5 (12)	-	-	-	13	1	204
								15 976

Bracketed numbers indicate number of days in cycle used to calculate mean

TABLE 3

Messages Received from Landsat-2 During Cycle 38 (Dec. 11 to Dec. 29, 1976)

PID	MESSAGES					ORBITS				
	Received at			Total	Discrete	Messages Received at			Total	Discrete
	A	G	N			A	G	N		
6102	2	15	88	105	98	2	15	59	76	67
6126*	7	7	0	14	11	7	7	0	14	9
6137*	16	27	80	123	113	16	24	44	84	65
6150	302	127	101	530	468	144	62	58	264	176
6210	0	0	100	106	106	0	0	49	49	49
6232	152	136	47	335	282	87	59	28	174	110
6260*	2	11	65	78	74	2	6	22	30	26
6353	343	131	136	610	546	146	61	68	275	185
6354*	127	74	14	215	176	78	48	12	138	88
6501*	10	21	0	31	21	10	[illegible]	0	28	18
6502*	2	0	12	14	14	2	0	7	9	8
6504*	5	17	86	108	92	5	8	26	39	30
6514	61	84	7	152	109	47	46	5	98	59
6524	4	26	179	209	194	4	15	74	93	80

* - Partial Cycle - see Table 2

A - Fairbanks, Alaska

G - Goldstone, California

N - Greenbelt, Maryland

IV. Significant Results

The project continues to demonstrate the feasibility of transmitting hydrometric data to polar orbiting spacecraft and using these data operationally. All elements on the system are functioning well.

V. Publications

On October 19, 1976, Mr. Halliday gave a report on the project to NASA's water resources panel. A copy of the notes for this talk are included in this report as an appendix.

On November 8, 1976, Mr. Halliday conducted a discussion on satellite data retransmission techniques for the Workshop on the Remote Sensing of Soil Moisture and Groundwater which was held in Toronto on November 8 to 10, 1976. The Workshop was sponsored by the Remote Sensing Society of the Canadian Aeronautics and Space Institute. No text was prepared.

On December 16, 1976, Messers Halliday and Chapman gave a talk on Equipment Development and Automation - Hydrometric Field Work at the First Annual Meeting of the Water Survey of Canada, Pacific Region. The talk covered several topics, one of which was satellite data collection. A text of the talk is available on request.

During the reporting period Dr. G.W. Kite and Mr. I.A. Reid prepared a paper for publication entitled Discrete Sampling of Hydrologic Data. This paper should be published within the next six months.

Mr. I.A. Reid prepared an article entitled Satellites Help the North for the Arctic Circular. This circular has a distribution list of approximately 1 000.

VI. Problems

The problem with DCPs 6527 and 6571 should be cleared-up in the near future as they are being repaired by Ball Brothers Research Corporation. The platforms had some manufacturing defects.

VII. Data Quality and Delivery

A check of the message quality of a 50 day period of Landsat DCS data showed the following results:

Message quality	0	1	2	3	4	5	6	7
No. of messages	103	4	9	18	16	43	96	14 767

The total number of messages received is 15 056 with 14 767 or 98% being quality 7.

Examination of a random sample of about a week of messages in 1976 revealed that it takes from a few minutes to several hours from the time the messages are transmitted by a DCP to the time the messages are received by dedicated phone line at the Canada Centre for Remote Sensing, Ottawa. Except for possible emergency situations, this time delay does not degrade the usefulness of Landsat data. The hard copy in card form arrives 10 to 14 days after the messages have been transmitted. Again this time delay does not degrade the usefulness of the system.

VIII. Recommendations

None, other than to continue operation of Landsat DCS.

IX. Conclusions

Results at this time have demonstrated the suitability of satellite retransmission as a means of obtaining near real-time data from remote areas of Canada. Capital costs of the DCPs and ancillary instruments are reasonable and the DCPs do not require much maintenance.

The potential impact of this technology on water resources data gathering activities is considerable.

RETRANSMISSION OF HYDROMETRIC DATA IN CANADA

-notes for an oral report to
NASA, 1976-10-19

Applied Hydrology Division
Department of the Environment
Ottawa, Ontario, Canada
K1A 0E7

R.A. Halliday
Principal Investigator
SR 28190

RETRANSMISSION OF HYDROMETRIC DATA IN CANADA

INTRODUCTION

Canada is a large, sparsely populated country having generally abundant water supplies. The Water Survey of Canada, a division of the Department of the Environment plays a major role in monitoring the availability and distribution of fresh water.

As hydrometric data are often required on an immediate basis from areas in which site access is difficult and costly, the potential of the Landsat Data Collection System (DCS) was immediately recognized and steps were taken to enable Water Survey of Canada experiments to test the system.

This talk will describe the Water Survey of Canada Landsat project in some detail, including references to other satellite data collection activities, and will speculate on the future of the technology in Canada.

THE PROBLEM

The Canadian land mass, measuring 10 000 000 km^2, is the second largest in the world while Canada's population of 23 000 000 is relatively small. Most of the population is in southern Canada, particularly in the Provinces of Ontario, Quebec and British Columbia thus making the rest of the country especially sparsely populated.

About 7.5% of Canada's surface area is covered with fresh water and total river flow has been estimated at about 100 000 m^3/s. This averages about 427 m^3 of water per person per day which is far greater than the USA figure of 23 m^3 per person per day. Unfortunately much of the Canadian runoff trends northward to the Arctic Ocean rather than into populated areas.

One of the roles of the Water Survey of Canada is that of monitoring river flows and lake levels at about 2400 gauging stations under agreement with the Provincial governments and making the data available to users. The uses of the data are myriad including hydroelectric power generation, water transportation, irrigation, flood control, domestic water supply and sanitation, fisheries, design of structures and interprovincial or international division of flow.

Many users require archival data, for example in designing a dam; others require real time data, for example, in division of flow; while others require forecast data, for example, in forecasting low flows for navigation. In order to meet the latter two needs, the Water Survey operates about 100 water level telemetry systems using telephone lines. For the vast majority of the gauging stations, however, it is prohibitively expensive to install either telephone or radio telemetry systems. Instead data needs are fulfilled to some extent by hiring a local observer to read a gauge and to report the readings by telephone or by mail on a daily, or even weekly, basis. Of course, in unpopulated areas, even this procedure cannot be used.

The need for improvements in providing real time data was therefore very apparent in the early 1970's when the first information concerning the Landsat (then ERTS) DCS was circulated in Canada. Proposal 532-G was submitted to NASA and subsequently approved as project SR No. 9629 and the follow-on project SR 28190 was also approved.

A SOLUTION

Initially it was decided to install 9 Data Collection Platforms (DCPs) at gauging stations in western and northern Canada to determine the suitability of the Landsat DCS. Sites were selected that would provide real time data for use in flow and flood forecasting and for planning hydrometric operations. It was hoped that Landsat DCS would provide one water

level reading each day. Because of the multi-parameter capability of the DCPs other hydrometeorological sensors were also tested at some sites.

The data retransmitted by Landsat were made available to users on a near real time basis through the use of a Teletype line to the Canada Centre for Remote Sensing (CCRS). Eventually, as the usefulness of satellite DCS became apparent, the network of the DCPs was significantly expanded.

Site Selection

The gauging stations at which DCPs have been installed since 1972 and the purpose of the installation are described below. Active stations are depicted in Figure one.

Illecillewaet River at Greely	Lat 50°38'	Long 117°03'
Duncan River below B.B. Creek	Lat 51°01'	Long 118°05'
Carney Creek below Pambrun Creek	Lat 50°10'	Long 116°35'
Snow Course No. 5A Mission Creek	Lat 49°57'	Long 118°55'

These gauging stations are in the Columbia River basin. Data are used by Canada and the USA in forecasting runoff. Also the Columiba River Basin Permanent Engineering Board uses the data to check the operation of the Columbia River Treaty dams. The DCPs on the Illecillewaet and Duncan Rivers were removed from these sites when conventional telemetry service became available.

McGregor River at Lower Canyon	Lat 59°14'	Long 121°40'
Nahatlatch River below Tachewana Creek	Lat 49°57'	Long 121°52'

These two gauging stations are on tributaries to the Fraser River. The data are used to compute tributary inflow to the Fraser River for flood forecasting.

Mackenzie River at Fort Simpson	Lat 61°52'	Long 121°21'
Mackenzie River at Norman Wells	Lat 65°17'	Long 126°51'
Mackenzie River near Wrigley	Lat 63°16'	Long 123°36'
Mackenzie River at Sans Sault Rapids	Lat 65°46'	Long 128°45'
Root River near the Mouth	Lat 62°29'	Long 123°26'
Liard River at Fort Liard	Lat 60°15'	Long 123°29'
South Nahanni river above Virginia Falls	Lat 61°38'	Long 125°48'
Mountain River below Cambrian Creek	Lat 65°14'	Long 128°34'

The DCP operation at the first two sites and on the Liard River has been discontinued. Data from the remaining six sites are used during the short summer shipping season to prepare daily water level forecasts for the Mackenzie River. The River is the main means of transporting bulk

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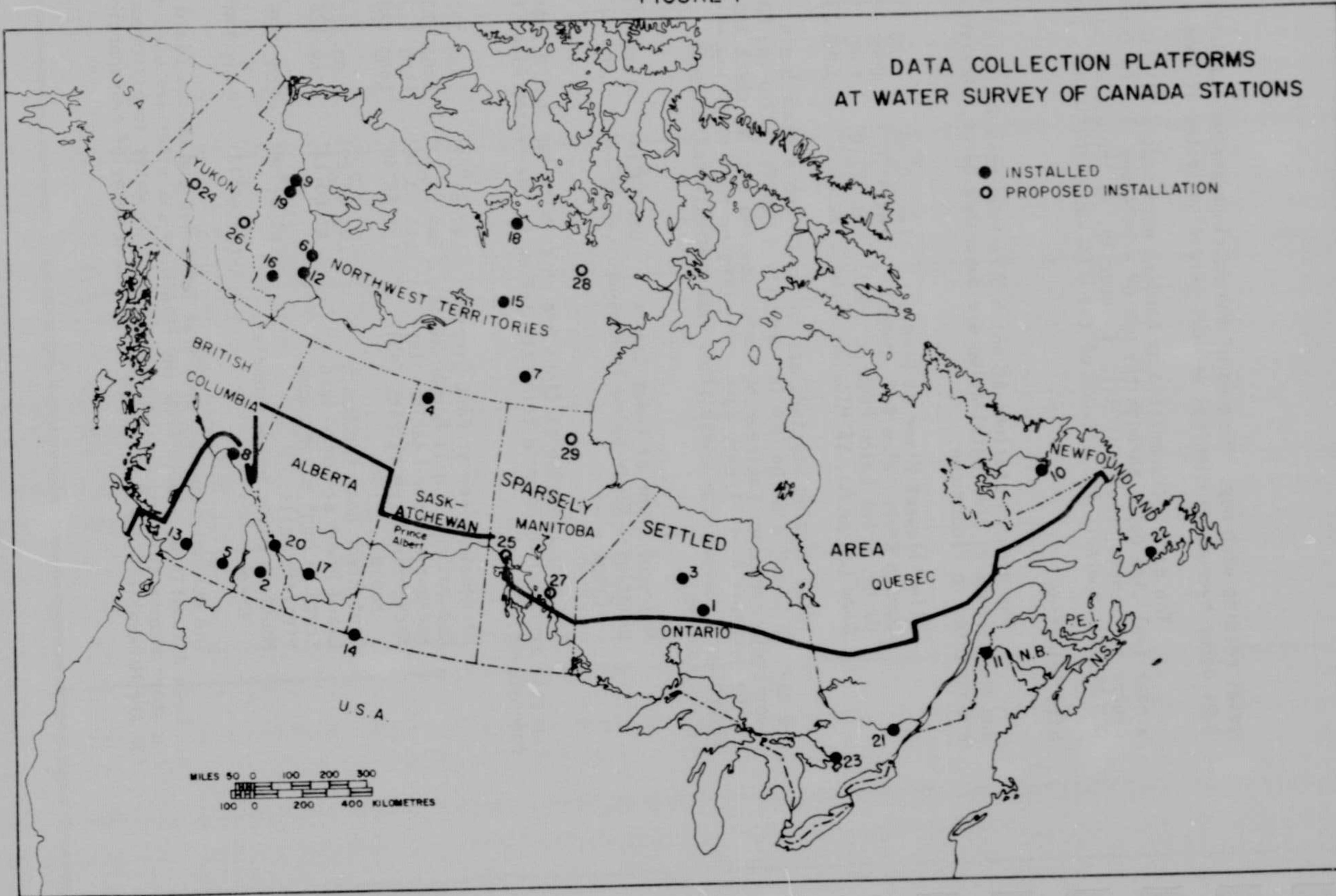
FIGURE I


DATA COLLECTION PLATFORMS
AT WATER SURVEY OF CANADA STATIONS
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YUKON
NORTHWEST TERRITORIES
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ALBERTA
SASK-ATCHEWAN
Prince Albert
MANITOBA
ONTARIO
QUEBEC
NEWFOUNDLAND
N.B.
N.S.
P.E.I.
SPARSELY SETTLED AREA
U.S.A.
USA
MILES 50 0 100 200 300
100 0 200 400 KILOMETRES

cargo for re-supply of settlements and for oil companies in the western arctic.

Hanbury River above Hoare Lake	Lat 63°31'	Long 105°09'
Kazan River at Outlet of Ennadai Lake	Lat 61°16'	Long 100°58'
Ellice River near the Mouth	Lat 67°42'	Long 104°08'
Albany River above Nottik Island	Lat 51°38'	Long 86°24'
Winish River at Kanuchuan Rapids	Lat 52°58'	Long 87°42'
Winish River below Asheweig River	Lat 54°31'	Long 87°14'

The data from these DCPs are used mainly in planning of hydrometric field work. Visits to the sites can be made at the most opportune times and, in the event of sensor failure, repairs can be made easily.

Lake Athabasca at Crackingstone Point	Lat 59°23'	Long 108°53'

Lake Athabasca acts as a reservoir, augmenting low summer flows in the Slave and Mackenzie River. As lake levels affect the wildlife in this area, levels transmitted by Landsat are used to monitor the situation. DCS data from this site are also used in preparation of a monthly bulletin entitled "Runoff Conditions in Canada".

Battle Creek at International Boundary	Lat 49°00'	Long 109°25'

The data from this DCP are used in computing ten day natural flows at the Canada-U.S. boundary so that water may be divided equitably between the two countries.

St. Francis River at Outlet of Glasier Lake	Lat 47°12'	Long 68°57'
Rivière Dumoine à la sortie du lac Dumoine	Lat 46°49'	Long 77°52'

Data from these two sites on tributaries to the Saint John and Ottawa rivers respectively were used as inputs to Streamflow Synthesis and Reservoir Regulation (SSARR) forecasting models of the watersheds. The rivière Dumoine site was on a Quebec Natural Resources gauging station and was run as a demonstration during the spring of 1976 and will likely be reactivated in the spring of 1977.

Severn River above Wasdell Falls	Lat 44°44'	Long 79°20'

This gauging station in the Trent-Severn Waterway, a major recreation area, is below the confluence of several small streams, all of which are regulated. The Severn River is also regulated downstream from the DCP site. The water level and water velocity data transmitted are used to compute river discharge so that various structures in the system can be operated effectively.

Churchill River at Muskrat Falls   Lat 53°15'   Long 60°47'

Water level data transmitted by this DCP are used to monitor the inflow to the Churchill Falls Hydro electric power project. The plant has a generating capacity of 5 x 10^6 kW and supplies power to the eastern part of the continent.

Grey River near Grey River   Lat 47°44'   Long 56°56'

Water level data from this site are used in an anadromous fisheries management program to monitor an agreement between Newfoundland Hydro Corporation and the Fisheries Service regarding minimum flows in the river.

Bow River below Carseland Dam   Lat 50°50'   Long 113°25'
Rideau River at Ottawa   Lat 45°23'   Long 75°42'

These two sites are used as test sites. All DCPs are checked at one of these locations prior to installation in remote sites. Also sensors are checked as well when trouble-shooting faulty units or testing new ones.

Sensors

Several sensors have been used with the Water Survey's DCPs although the principal parameter transmitted is water level. These sensors are tabulated in Figure two.

Water levels are sensed by one of two methods. The most frequently used is a float and pulley operating in a stilling well that is connected to the stream. As the float rides up and down in the well it produces analogue shaft rotations. Where use of stilling wells is not feasible, a nitrogen purge system is used to sense the head of water above a fixed orifice near the stream bed. This head is also converted to a shaft rotation by means of a servomanometer. At standard gauging stations the shaft rotations produced by the float or by the servomanometer are converted to recorder pen movements by mechanical linkages. However, when DCPs are installed an analogue to digital encoder is used to encode water level as 4 or 5 BCD digits. The interface, known as the Stevens Memomark II is connected directly to the parallel digital input of the DCP.

Two different water velocity sensors have been used. A Marsh-McBirney electromagnetic meter was installed on the Nahatlach River. This meter measures velocity at a point using the Faraday principle. It was thought that, since the meter had no moving parts, it would not be as subject to fouling as meters having moving parts. The analogue output of the meter was integrated by a specially designed interface then transmitted in parallel digital by the DCP.

The other water velocity sensor is an Atlas FLORA 10 acoustic flow meter that was installed on the Severn River. This instrument measures the integrated velocity on a line between two transducers, one on either

SENSORS USED WITH WATER SURVEY OF CANADA LANDSAT DCPs

PARAMETER	SENSOR	INSTRUMENT	INTERFACE
WATER LEVEL	FLOAT PRESSURE	STEVENS MEMOMARK II CAE SERVOMANOMETER	CONTAINED IN MEMOMARK STEVENS MEMOMARK II
WATER VELOCITY	ELECTROMAGNETIC ACOUSTIC	MARSH-MCBIRNEY ATLAS FLORA 10	ANALOGUE INTEGRATOR NONE REQUIRED
ICE CONDITION	ELECTRO-MECHANICAL	NOT APPLICABLE	NONE REQUIRED
RECORDER OPERATION	ELECTRO-MECHANICAL	NOT APPLICABLE	NONE REQUIRED
PRECIPITATION	WEIGHING TYPE	FISCHER & PORTER	HARTS UNIT
TEMPERATURE	PLATINUM RESISTANCE BULB		HARTS UNIT
	THERMISTER	YSI 44033	
SNOW WATER CONTENT	SNOW PILLOW	PRESSURE TRANSDUCER	NONE REQUIRED
DCP BATTERY VOLTAGE	ELECTRONIC	NOT APPLICABLE	NONE REQUIRED

side of the river, every ten minutes. This instrument also has no moving parts. The velocity reading is available for telemetry in the instrument as 3 BCD digits or an analogue voltage (scaled 0 to 10 volts).

For those DCP equipped gauging stations whose transmissions are used mainly in planning hydrometric operations, some ice condition indicators were devised and installed. These are used simply to indicate the presence or absence of ice in the channel so that personnel will know when it is safe to fly into a site in the spring using float equipped aircraft. The sensor uses one parallel digital bit.

Another sensor was devised to indicate that the standard water level recorder clock was operating. It was felt that if the DCP data showed that there was no reason to visit a site, visits could be postponed thus saving operational money. The sensor is a simple cam and switch arrangement that uses two parallel digital bits.

As runoff conditions are closely related to meteorological conditions, some meteorological data have also been transmitted from the DCP sites. These include:

> Precipitation from a Fischer & Porter weighing type gauge. This uses 12 bits of the DCP message, either serial or parallel digital depending on sensor used.
>
> Air temperature, either from a platinum resistance bulb or thermistor. This uses either one or two analogue channels, depending on whether a reference voltage is also transmitted.
>
> Snow water content from a snow pillow connected to a pressure transducer. The transducer has an analogue output and uses one channel on the DCP.

Finally, in order to monitor DCP battery voltage, a battery voltage sensor was devised. The DCP battery voltage is scaled to the range 0 to 5 volts and transmitted on one analogue channel.

Data Collection Platforms

As stated earlier 9 DCPs were used in the initial program. These were manufactured by the General Electric Company as part of the order delivered in 1972. An additional GE DCP (originally used by another Principal Investigator, Dr. J. Kruus) has also been used at Water Survey gauging stations.

The 19 DCPs purchased for the follow-on program were manufactured by the Ball Brothers Research Corporation and delivered in 1975. These DCPs are convertible between the Landsat and GOES systems.

One Bristol Aerospace GOES DCP has also been purchased as part

of the data retransmission program and an order for three LaBarge Landsat/GOES convertible DCPs is under preparation.

One 720 bit DCP memory was purchased from Ball Brothers. The memory was originally used with a GE DCP but has now been installed in a Ball DCP.

Data Handling and Processing

All messages relayed by Landsat are received in Alaska, California or Maryland then sent over NASCOM lines to the Goddard Space Flight Center in Greenbelt, Maryland. The Canadian messages having quality seven are sent by Teletype to the Canada Centre for Remote Sensing (CCRS) in Ottawa, usually within 15 to 20 minutes after each Landsat pass. At CCRS the data are recorded simultaneously on a teletype hard copier and on magnetic tape. A software data retrieval system sorts the user data platforms, reformats the data into engineering units and stores individual user files on disk. A user may then access the file, usually daily, using a Teletype or Telex remote terminal.

In addition to this near real time operation, NASA also provides the data in punched card and uncalibrated computer listings about two weeks after transmitted by the DCP. These data are delivered to the Canadian Embassy in Washington, D.C., then carried by diplomatic bag to the Department of External Affairs in Ottawa. The Department then mails the data to users. The cards are run through a computer to sort the data and to perform conversions to engineering units. The cards are thus used to produce archival data and also to generate statistics on DCP performance.

Work is in progress concerning implementation of a Landsat/GOES DCS receive capability at the Prince Albert (Saskatchewan) Satellite Station. Data should be available in engineering units to users having Teletype or Telex in May, 1977.

RESULTS

The experimental use of Landsat data relay has proved to be an outstanding success; so much so that all DCPs are now operated on a quasi-operational basis. The results of various aspects of the program are described in the following sections.

Sensors

Nearly all sensors have performed as expected. Some minor problems were encountered with the timers used in the Memomark II water level encoder, especially in extremely cold temperatures. The only sensor that did not perform as expected was the Marsh-McBirney velocity meter.

This became fouled very easily and, in at least one instance, was overturned by waterborne debris. The experiment was eventually discontinued.

Documented cases of the ice condition and recorder operation sensors' performance have occurred.

Data Collection Platforms

The data collection platforms have proved easy to install and operate. Some difficulty was experienced in handling the GE antenna in small aircraft as it was necessary to remove the antenna from its shipping box. Therefore the antenna had to be protected by other means. The Ball microstrip antenna was a significant improvement in size over the GE antenna with little or no decrease in performance.

It was found that snow accumulations up to one metre in depth on the antenna ground-plane did not affect DCP performance. One GE ground-plane was damaged by snow loads, but performance was not affected. The antennas have not been affected by strong winds.

As the GE DCPs showed a temperature specification of only -40^{0}, it was decided to heat some units. An insultated enclosure made of plywood and expanded polystyrene beadboard was constructed and heated using a 300 kJ capacity catalytic propane heater. It was subsequently found that some GE units would operate at temperatures below -40^{0} and also the Ball units would operate at temperatures lower than their -20^{0} specification.

The power supply for the DCPs usually is two 12 V heavy duty car batteries. Rechargeable alkaline batteries, charged by solar panels are also used. An experiment is being conducted using air depolarized potash cells as a DCP power supply. The cells are non-rechargeable but should have a long lifetime. One set has been in continuous use for over two years - the only difficulty is that the battery cannot supply the peak current requirements at temperatures below -25^{0}. At the site selected for the experiment, this does not cause much of a problem.

The DCPs have proved to be remarkably trouble-free once they have been placed in service. Some GE DCPs have been in almost continuous operation for over four years without any problems. Four of them did fail - one was believed to be struck by lightning, one failed due to corrosion on the programmer board (connectors A3J1, A3J2, A3J3 and ICs U25-27, U29-27, U29-30, U34 and U36-39), one failed due to peeling of the zinc coating on the transmitter board's heat sink and the last failed because of an IC failure on the programmer board (IC U38). The Ball DCPs (first installation in August, 1975) have not been in operation long enough to develop failures. It is noteworthy that several of the Ball DCPs had manufacturing defects. Repairs can be difficult as the manufacturer's documentation is not good.

In 1976, small RF testers became available from GFA Engineering

Inc. These have proved very useful in deploying DCPs as the DCP can be checked before leaving a site. It was hoped that the Field Test Set that was purchased from GE in 1972 would fill this need. However that unit tended to disintegrate when transported and often indicated that a good DCP was not working. The GE Test Set has not been used since 1973.

Data Handling and Distribution

In retrospect, the stated aim of the original experiment i.e. "to receive a discrete water level from each of nine sites each day" seems to be a classic case of cautious optimism. Even prior to implementation of the Alaska receive site data were received as many as seven orbits each day with over twenty messages being received each day. Since the Alaska down-link was installed some northern DCPs have averaged nearly ten orbits a day on which data are relayed and over thirty messages a day is not uncommon.

The data assigned message quality 7 are accurate.

The near real time data provided by the Teletype line to CCRS have proved extremely valuable but, since the quality of the data on the line sometimes is degraded, the data sent in card form are also valuable for archival purposes. The real time data have been used in flow and flood forecasting and in hydrometric trip planning. Data have been used by several government agencies.

Although the original interest in Landsat DCS was prompted by its capacity to provide near real time data, it has become increasingly apparent that satellite retransmission can also be used as a primary data collection tool. A study is in progress to determine the optimum sampling interval at gauging stations in the various physiographic regions of Canada. The results will provide information that will be useful in developing procedures for using DCP memories. The results to date indicate that, for some streams, a three hour sampling interval provides surprisingly accurate streamflow data. Certainly, it seems that a 15 minute sampling interval could be "overkill".

WHERE DO WE GO FROM HERE?

The Landsat DCS program has proved to be very successful for the Water Survey of Canada so the logical question is, "where do we go from here?" There is unquestionably a need for data retransmission from additional Water Survey of Canada gauging stations. Besides the use of this information for flow and flood forecasting purposes, there seems to be strong evidence that use of DCPs at many sites would result in savings in operational costs or improved data quality as conditions at the gauging station would be known at all times.

For example, about 300 gauging stations in Canada can be considered as "remote access". This means access is generally by fixed or rotary winged aircraft thus access costs are higher than average. Also the site is visited by a two person rather than one person field party. Sites are visited five to ten times each year so, if an assumption is made that one visit a year to each station could be eliminated, the cost of a DCP can be recovered well within its useful life.

Typical aircraft costs are:

Twin Otter	\$360/hr
Jet Ranger	\$300/hr
Single Otter	\$220/hr

Charter aircraft companies usually specify a minimum daily rate of at least four hours.

As a visit to a site may take two to four hours (depending on the gauging station and the work performed), it's apparent that an average annual saving in field travel costs of \$1000 would be reasonable especially if all travel costs are included. It can be seen therefore that, if the cost of a DCP plus water level encoder is assumed to be \$5000, the capital cost of satellite telemetry is recovered in 5 years. In a rigorous example some benefit should also be assigned to the real time availability of the data and to the probable increase in quality of the record while some cost should be given for operation of the data distribution system and to DCP maintenance.

There is also another group of Water Survey of Canada gauging stations that lend themselves to satellite telemetry. These are the 500 tide gauging and inland lake stations where only water level data are collected. Very few of these stations are remote access but, since there is no requirement to visit the stations to obtain discharge measurements, the number of visits to the site could be cut to two or three (from ten or twelve) a year if memory equipped DCPs were used as the primary data collection tool. Savings in field travel costs would be relatively small, say \$200 a year, but many of these water level stations now have local observers that are paid \$300 to \$1000 a year so, once again, the cost break becomes favourable.

At present, one of the major factors inhibiting any movement to large scale (by Canadian standards) deployment of DCPs is the lack of an operational satellite system that meets all requirements. Such a system must provide coverage of all of Canada several times a day and, preferably, be able to handle variable message lengths. Because of Canada's high latitudes, a polar orbiting two or three satellite system is required to achieve complete coverage, both areal and temporal. The Argos system carried by Tiros-N may meet a sufficient number of requirements to spur more widespread deployment of DCPs. Work is also in progress in Canada on a system design study for a data collection and fisheries surveillance satellite. The GOES system may fulfil some requirements.

In anticipation of more widespread deployment of DCPs, some work on DCP development and DCS ground stations has been funded. Both of these activities will continue for at least another year.

Use of the Landsat data collection system will continue as long as the service remains available and the existing DCPs continue to operate.

CONCLUSION

The use of the Landsat data collection system in transmitting water resources data from isolated areas of Canada to users has demonstrated the suitability of such technology for meeting Canadian needs. The retransmitted data have been used in many applications and the entire system has proved to be effective. Further expansion of the satellite DCS program is warranted.

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